Properties and Classifications of Matter

PS-3 The student will demonstrate an understanding of various properties and classifications of matter.

PS-3.7 Explain the processes of phase change in terms of temperature, heat transfer, and particle arrangement.

Taxonomy Level: 2.7-B Understand Conceptual Knowledge

Key Concepts:

Temperature
Phase change (in terms of energy): freezing/melting point, boiling point, sublimation
Temperature change (in terms of energy)
Heat Energy

Previous/Future knowledge: Students in 3rd grade explained how water and other substances change from one state to another (including melting, freezing, condensing, boiling, and evaporation (3-4.2). In 7th grade students revisited changing states of matter as a physical change along with melting and boiling points as properties.
The Physical Science indicators appear to be very similar to 3rd grade, but Physical Science students have developed a conceptual image of atoms and molecules and are more cognitively prepared for a deeper understanding of phase change in terms of the kinetic theory and energy changes.

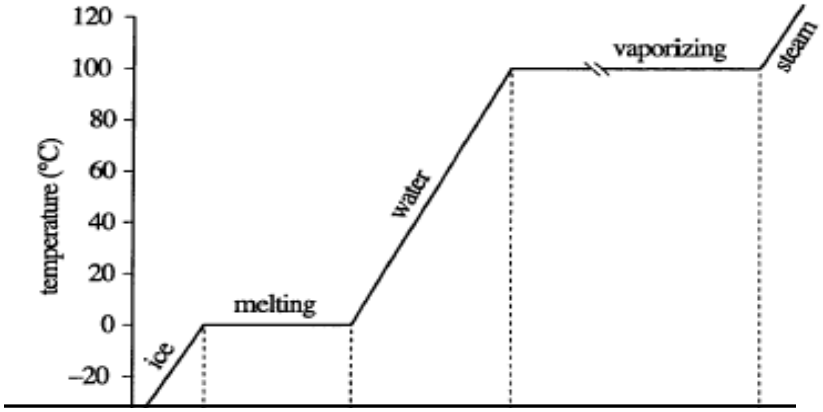
It is essential for students to

- Understand that *temperature* is a term used to describe the average kinetic energy of the particles in a substance. In a sample of material at any temperature there are particles moving at all speeds. Temperature is a measure of the average motion of the particles. At higher temperatures, more of the particles are moving fast and at lower temperatures, more of the particles are moving slowly.
- Explain *phase change* in terms of the kinetic theory.
  - Phase change is due to *changing* the freedom of movement of the particles by the addition of energy.
  - The freezing/melting point is the temperature where a phase change occurs as both the liquid and solid phases exist in equilibrium with each other. If heat energy is being added at this temperature, bonds between particles will break and a solid will melt. If heat energy is being taken away, bonds will form between particles and a liquid will freeze at this temperature.
  - The boiling point is the temperature where a liquid is changing to a gas throughout the liquid. Evaporation at the surface of a liquid can occur at any temperature. However, at the boiling point bubbles of the vapor are formed throughout the sample and rise to the top and escapes at which point the sample is said to be boiling.
- Understand that when energy (such as heat) is added to a substance, the energy of the particles of the substance increases. Evidence of this would be that: (1) the temperature of the substance increases, or (2) a phase change occurs.
- Understand that when heat is added to a solid the particles will move faster and the temperature will increase until the temperature of the solid reaches its melting point.
  - When the temperature of a solid is equal to the *melting point* and more heat is added to the substance, the temperature will not change. The extra heat will be used to break some of the bonds between the molecules of the solid and change the phase to a liquid.
- Understand that when heat is added to a liquid the particles will move faster and the temperature will increase until the temperature of the liquid reaches its boiling point.

- When the temperature of a liquid is equal to the *boiling point* and more heat is added to the substance, the temperature will not change. The extra heat will be used to break the bonds between the molecules of the liquid and change the phase to a gas. When a substance boils, it forms bubbles of the gas. (For example when water boils, the bubbles are filled with water vapor.)

- Understand the changes shown on a temperature versus time graph that shows boiling point and melting/freezing point.
  - The line of the graph has a positive slope until a phase change occurs.
  - At the melting point or boiling point the temperature does not change as more heat is added over time. The slope of the line will be flat during the time that the phase is changing.
  - After the phase change the slope of the line becomes positive again.

Heat Added Over Time



- Understand that liquids may evaporate at any temperature. This is because some of the molecules at the surface are moving fast enough to escape the attraction of the other molecules.
- Understand that solids may undergo the process of *sublimation*, a process that involves particles changing directly from the solid phase to the gaseous phase. This is a process similar to evaporation that takes place at the surface of the solid.
  - An example of sublimation is seen when dry ice (solid carbon dioxide) disappears as it changes directly to gaseous carbon dioxide without melting first.

Misconceptions:

- Students often confuse heat with temperature.
  - Sometimes it is helpful to point out that a huge pot of very hot water and a coffee cup of very hot water can both have the same temperature, but the pot of water contains much more heat energy than the water in the cup because the mass of the water in the pot is so much greater.
  - This concrete example helps students to understand that there is a distinction in the two concepts, even though it is beyond the scope of this course for students to fully explore the distinction in the two.
- The only distinction that is essential for Physical Science students to make is that heat is a form of energy and temperature is an indication of the average kinetic energy (and therefore the speed) of the particles.

Properties and Classifications of Matter

PS-3 The student will demonstrate an understanding of various properties and classifications of matter.

It is not essential for students to

- Understand the effect that pressure has on phase change;
- Differentiate heat and temperature in quantitative terms (Addressed in subsequent chemistry/physics classes);
- Understand how the mass of the particles of a substance affect the energy of the particles.

Assessment Guidelines:

The objective of this indicator is to *explain* the processes of phase change in terms of temperature, heat transfer, and particle arrangement, therefore, the primary focus of assessment should be to construct cause and effect models of phase change based on the kinetic theory of matter. The cause and effect required by assessment is not a statement such as "the solid melts because heat is added when it is at a temperature equal to its melting point"; the cause and effect required by assessment is a model of the system such as "a solid will melt when the solid absorbs enough energy at its melting point to overcome/break the attractive forces between the particles."

In addition to *explain*, assessments may require that students

- *Illustrate* with words, pictures, or diagrams phase change processes related to energy change;
- *Recognize* what happens to temperature between phase changes and during phase change;
- *Summarize* major points about what happens to particles and particle arrangement during phase change in terms of kinetic theory;
- *Identify* a phase change based on the description of particle arrangement and temperature change.